Staged Management of Giant Abdominal Wall Defects

Acute and Long-Term Results

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Introduction: Shock resuscitation leads to visceral edema often precluding abdominal wall closure. We have developed a staged approach encompassing acute management through definitive abdominal wall reconstruction. The purpose of this report is to analyze our experience with this technique applied to the treatment of patients with open abdomen and giant abdominal wall defects.

Methods: Our management scheme for giant abdominal wall defects consists of 3 stages: stage I, absorbable mesh insertion for temporary closure (if edema quickly resolves within 3–5 days, the mesh is gradually pleated, allowing delayed fascial closure); stage II, absorbable mesh removal in patients without edema resolution (2–3 weeks after insertion to allow for granulation and fixation of viscera) and formation of the planned ventral hernia with either split thickness skin graft or full thickness skin closure over the viscera; and stage III, definitive reconstruction after 6–12 months (allowing for inflammation and dense adhesion resolution) by using the modified components separation technique. Consecutive patients from 1993 to 2001 at a single institution were evaluated. Outcomes were analyzed by management stage, with emphasis on wound related morbidity and mortality, and fistula and recurrent hernia rates.

Results: Two hundred seventy four patients (35 with sepsis, 239 with hemorrhagic shock) were managed. There were 212 males (77%), and mean age was 37 (range, 12–88). The average size of the defects was 20 × 30 cm. In the stage I group, 108 died (92% of all deaths) because of shock. The remaining 166 had temporary closure with polyglactin 910 woven absorbable mesh. As visceral edema resolved, bedside pleating of the absorbable mesh allowed delayed fascial closure in 37 patients (22%). In the stage II group, 9 died (8% of all deaths) from multiple organ failure associated with their underlying disease process, and 96% of the remaining 120 had split-thickness skin graft placed over the viscera. No wound related mortality occurred. There were a total of 14 fistulae (5% of total, 8% of survivors). In the stage III group, to date, 73 of the 120 have had definitive abdominal wall reconstruction using the modified components separation technique. There were no deaths. Mean follow-up was 24 months, (range 2–60). Recurrent hernias developed in 4 of these patients (5%).

Conclusions: The staged management of patients with giant abdominal wall defects without the use of permanent mesh results in a safe and consistent approach for both initial and definitive management with low morbidity and no technique-related mortality. Absorbable mesh provides effective temporary abdominal wall defect coverage with a low fistula rate. Because of the low recurrent hernia rate and avoidance of permanent mesh, the components separation technique is the procedure of choice for definitive abdominal wall reconstruction.

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Fluid resuscitation from hemorrhagic and septic shock results in significant soft tissue edema. The bowel is not spared, and this visceral edema often precludes abdominal wall closure after celiotomy because the fascia cannot be approximated without excessive tension. Closure under tension often leads to fascial necrosis or abdominal compartment syndrome. Recognition of those complications has led to a widespread application of leaving the abdominal cavity open after either primary surgery or after decompressive laparotomy for established compartment syndrome. A wide variety of techniques have been applied for management of the resulting acute defect, whereas a paucity of information has been reported concerning definitive management of the large ventral hernias, which result when the abdomen has been managed in an open fashion after a catastrophic shock insult.

Polypropylene mesh has been used for temporary closure but has been associated with infection, mesh extrusion, and fistula. Intestinal fistulization remains the most morbid complication associated with the acute management of the open abdomen. Fistula rates of 12–50% have been reported when prostheses are used for acute management.[1–3] Other methods of maintaining the viscera in the abdominal cavity during the initial phase have included acute coverage with intravenous solution bags, closure with zipper or Velcro-type devices sewn to the fascial edges, and vacuum dressing approaches.[4–7] We reported an initial experience with a

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staged approach to management of these defects a decade ago after experiences with acute coverage using most of the aforementioned materials.[1] Over time, we began to steadily adopt absorbable mesh for acute management, which ultimately became our acute prosthesis of choice.

When prosthetic materials are subsequently used for definitive abdominal wall reconstruction, the most important complications are prosthetic infection and recurrent hernia. Although gram-positive infections occasionally occur in association with permanent mesh used for reconstruction, many infections result when mesh is inserted in the face of intestinal contamination from either associated ostomy closure or fistula excision, which are commonly associated with management of the initial insult. Recurrent hernia rates of 15–50% have been reported with the use of polypropylene mesh for definitive reconstruction of large abdominal wall defects.[1,8] We reported a small number of definitive reconstructions using local tissue transfer without permanent prostheses to avoid the complication of infected foreign body, and in attempt to reduce recurrent hernia rates.[1] Since that time, we have added modifications to the acute management of the open abdominal wall defects and have also developed a sizable experience with definitive reconstruction using a modified components separation reconstruction technique. That technique uses local myofascial tissue transfer and usually avoids the need for permanent prosthetic material for hernia repair. The present study was performed to analyze results of both acute and long-term management including definitive reconstruction with this staged approach.

METHODS

The patient population included consecutive patients with giant abdominal wall defects treated from October 1993 to October 2001. The defects resulted from managing patients with severe hemorrhagic or septic shock with the open abdomen technique. Most of the patients were those who developed massive intestinal edema precluding primary abdominal closure without undue tension after initial laparotomy whereas a small number had decompressive laparotomy for established abdominal compartment syndrome.

The staged management technique consisted of the following:

- Stage I: Absorbable mesh (polyglactin 910 woven mesh) insertion for temporary closure. When edema resolved within the first week, the mesh was gradually pleated, allowing delayed fascial closure.
- Stage II: Mesh removal in patients without edema resolution (2 to 3 weeks after insertion to allow for granulation and fixation of viscera) and formation of a planned ventral hernia using either a split-thickness skin graft (STSG) or full-thickness skin closure over the granulation tissue.
- Stage III: Definitive reconstruction after 6 to 12 months (allowing for inflammation and dense adhesion resolution) using the modified components separation technique.

The modified components separation procedure for abdominal wall reconstruction involves fascial separation and local advancement of muscle and fascia. Figure 1 illustrates the technique. The reconstructive procedure begins with removal of the STSG. The skin graft is removed by picking it up in an area in the midportion, which is not adherent to the underlying viscera. It is incised at that point and, using a combination of blunt and sharp dissection, adhesions between graft and abdominal contents are dissected. The graft is then excised from the healed edge of the attachment to the full thickness abdominal wall. The process of STSG excision generally takes 30 to 45 minutes. Next, the full-thickness skin flaps are dissected from the fascia bilaterally to approximately the midaxillary line to allow for identification of the fascial layers of the abdominal wall for the components separation. Bilaterally, the external oblique component of the anterior rectus sheath is then divided around 1 cm lateral to the rectus muscle and continued longitudinally approximately 6 to 8 cm over the costal margin superiorly, and inferiorly to the pubis. After division of the external oblique fascia, the posterior rectus fascia is separated from the rectus muscles

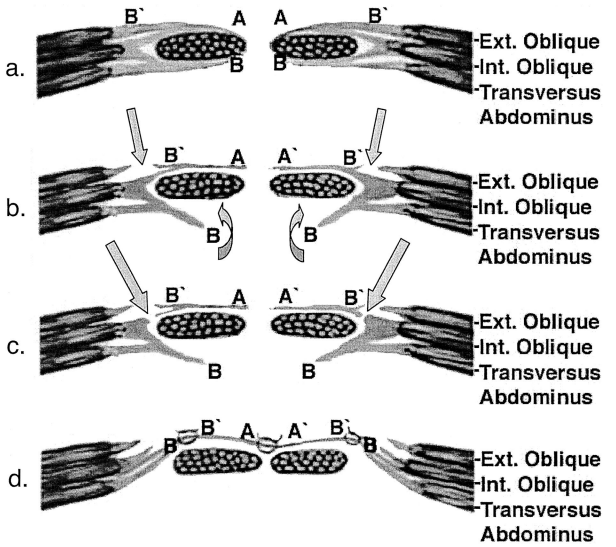

FIGURE 1. Modified components separation technique for abdominal wall reconstruction. A, Normal anatomy above the arcuate line. B, The posterior rectus sheath is mobilized from the rectus muscle (curved arrows), and the external oblique fascia is divided (straight arrows). C, The internal oblique component of the anterior rectus sheath is divided down the arcuate line. D, Completed repair, suturing the medial border of the posterior sheath (B) to the lateral border of the anterior sheath, (B′) with approximation of the medial portion of the anterior sheath (A to A′) in the midline.

bilaterally. Care must be taken not to injure the epigastric vessels during this portion of the dissection. The last separation is the internal oblique component of the anterior rectus sheath. This is divided superiorly from the costal margin and extending inferiorly to the arcuate line. Division must stop at that point because there is no posterior fascia below the arcuate line. Anatomic consideration of the blood supply to the rectus muscles demonstrates why this modification is effective. The blood supply to the rectus muscles is from the superior epigastric and deep inferior epigastric arteries, with the inferior epigastric providing the major component.[9,10] The inferior epigastric is a branch of the external iliac artery and lies between the internal oblique and transverse abdominis muscles. It enters the rectus sheath around the arcuate line and travels cephalad up the middle of the rectus abdominis and superiorly has anastomotic connections with the superior epigastric artery. Therefore, lateral division of the anterior sheath does not compromise blood supply. After the division of those fascial components, the rectus muscles and their anterior fascia are completely mobile from the other abdominal wall musculature. Reconstruction is completed by suturing the most medial portion of the posterior rectus fascia to the lateral portion of the anterior rectus fascia, bilaterally. (Fig. 1) This is accomplished by the use of 2 separate running #1 polypropylene sutures on each side. The abdomen is then closed at the midline by approximation of the medial components of the anterior rectus fascia with 3 separate running #1 polypropylene sutures. This components separation provides approximately 8 to 10 cm of mobilization in the epigastric area, 10 to 15 cm in the midabdomen, and 6 to 8 cm in the suprapubic region, on each side. Four closed suction drains are placed in the wound (two superior and 2 inferior).

Routine patient demographics and clinical characteristics were recorded. These included age, gender, and disease process. Outcomes were analyzed by management stage. Those outcomes included mortality rate, hospital length of stay associated with the initial disease process, and intestinal fistula rate. Outcomes associated with the reconstructive stage included the need for use of adjunctive mesh for repair and hernia recurrence rate.

RESULTS

Over the 8-year period of study, 274 consecutive patients underwent staged management for their open abdomens. During the time frame of study, there were nearly 2700 laparotomies performed for abdominal trauma. Thus, approximately 10% of patients undergoing laparotomy were managed with the open abdomen technique because of visceral edema. Eighty-seven percent of the study group suffered from hemorrhagic shock whereas 13% had septic shock from abdominal infection. Males accounted for 77% and females for 23%. The mean age of the patients was 37 years with a range of 12 to 88 years. Nearly all of the patients had midline incisions from xiphoid to pubis. This resulted in an open abdominal wound measuring approximately 30 cm × 20 cm in those who could not have their mesh pleated and secondary fascial closure.

Figure 2 provides an overview of the study population according to the staged management technique. There were 108 (39%) early deaths associated with the shock insult while the remaining 166 patients with open abdomen had absorbable mesh placed at stage I. Of those patients having mesh placed, 22% were able to have bedside pleating performed over the course of the first week resulting in secondary closure of the fascia. The remaining 129 patients had no edema resolution generally because of sustained inflammatory response and/or sepsis, and they were unable to have secondary fascial closure. Those 129 patients had granulation of the wound occurring over the course of 2 to 4 weeks after injury and 120 of the 129 underwent wound coverage (96%) with STSG and 4% with mobilization of full-thickness skin subcutaneous fat closed over the granulation. Nine of the 129 patients who survived to stage II succumbed to sepsis and multiple organ failure; the total mortality of the 274 patients with open abdomens was 117 patients (43%). Of the 120 patients who had wound coverage of the open abdomen, 73 (61%) have been reconstructed with the modified components separation technique. There have been no deaths associated with reconstruction. Forty-seven patients have not been reconstructed or were lost to follow-up. The timing from initial hospital discharge to reconstruction is determined by resolution of dense intra-abdominal adhesions. This biologic determination is made by following the inflammatory/healing process by evaluating the characteristics of the adherence of the STSG to the underlying viscera. For several months, the graft is indurated with firm attachment to the underlying intra-abdominal contents (liver, omentum, and intestines). However, in the time interval of 6 to 12 months, the adhesions generally become much more pliable and the adhesions flimsy, and the skin graft can be easily pinched from the majority of the underlying viscera. But, it is worth noting that the adhesions between the graft and liver generally do not resolve to the same degree as those from graft to intestines and care should be taken to not dissect in the subcapsular plane of the liver or troublesome oozing will result.

Fistulae

Fourteen fistulae developed in the 167 survivors (8.4%). All of these fistulae developed through the open wound. Ten were small intestinal, 3 colonic, and 1 was gastric. One of the 14 developed before mesh insertion and was a result of the primary injury. Ten fistulas developed after application of the absorbable mesh; a couple of those resulted from vigorous coughing and straining associated with pulmonary toilet, with splitting of the intestine, whereas

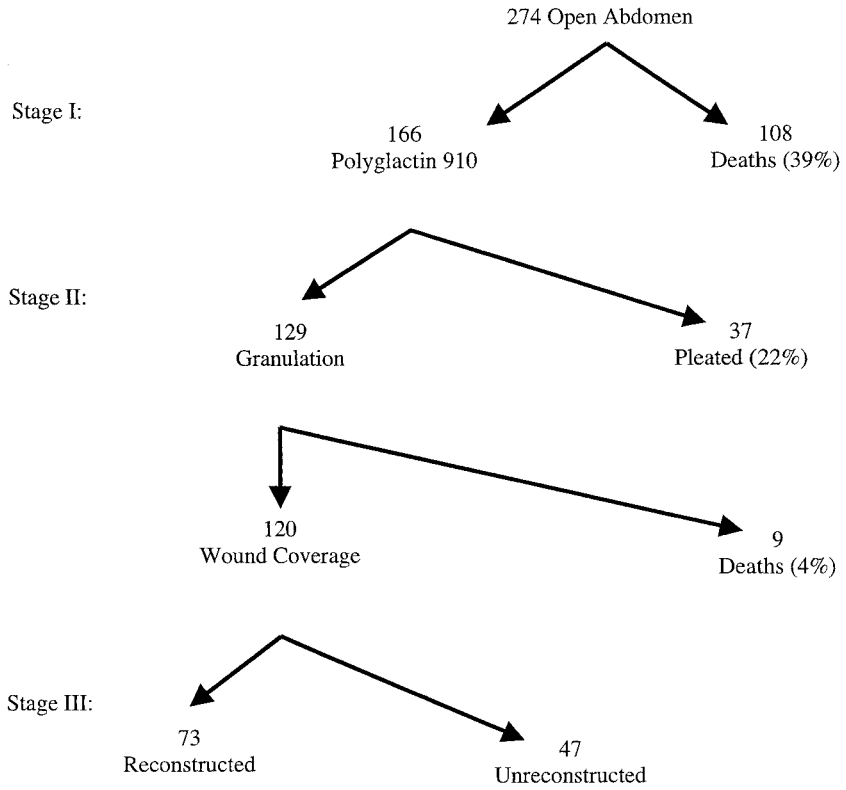

FIGURE 2. Staged management patient population

most were spontaneous and mesh erosion was thought to be largely responsible.

Duration of mesh application prior to coverage of the granulating wound appeared to contribute to the development of intestinal fistula (Table 1). The duration of mesh before wound coverage in the 10 patients developing fistula after mesh application was 26.5 days; this contrasts with an average of 18.1 day of mesh application in the 110 patients who did not develop fistula ($P = 0.04$). Three patients developed fistula after STSG of their open wounds (25, 40, and 180 days); the 2 early fistulas developed spontaneously through the graft without demonstrable etiology while the other fistula occurred at 180 days in a psychotic patient who manipulated his skin graft.

TABLE 1. Relationship of Time Interval of Absorbable Mesh Insertion to Either Removal or Development of Intestinal Fistula From During Stage II*

Fistula	Mesh Duration
Yes (n = 10)	26.5 days*
No (n = 110)	18.1 days*

*See Figure 2.

Eleven of the 14 fistulae were low volume. Skin grafting of the wound was accomplished along with local fistula control including frequent dressing changes, octreotide and atropine/diphenoxylate. The fistulae were then treated as ostomies and covered with an appliance while waiting for definitive reconstruction. The remaining 3 were high-volume fistulae which required early resection. Those procedures were difficult, requiring lysis of the dense adhesions and granulation tissue and fistula resection with anastomosis. Two of the 3 had skin grafts placed after fistula excision and the third had polyglactin 910 mesh placed, followed by granulation and skin grafting.

Definitive Abdominal Wall Reconstruction

Recurrent hernias have developed in 4 of the 73 patients (5%) who have undergone modified components separation repair of their abdominal wall. The average follow-up has been 24 months with a range of 2 to 60 months. Seven of the 73 patients (10%) required a small piece of permanent mesh as an adjunct to repair due to inability to close the wounds without tension. As with the complication of fistula, timing appears to be an important issue relative to reconstruction.

Considering time interval as a continuous variable, of the 9 patients who had either a recurrent hernia, or the need

TABLE 2. Relationship of Time Interval of Hospital Discharge to Abdominal Wall Reconstruction Related to Complications During Stage III*

Modified Components Separation Reconstruction Complication†	Interval Hospital Discharge Discharge to Reconstruction
Yes (n = 9)	19.5 months‡
No (n = 64)	11.6 months‡

*See Figure 2.
†complication = need for adjunctive mesh, recurrent hernia, or both.
‡$P = 0.1$, Fischer's exact test.

for adjunctive mesh, or both (5 adjunctive mesh, 2 recurrent hernias, and 2 recurrent hernias plus adjunctive mesh), the average time from hospital discharge for primary illness to definitive reconstruction was 19.5 months which compared with 11.6 months for 64 patients with definitive reconstruction without recurrent hernia or need for adjunctive mesh (Table 2). Considering time interval as a dichotomous variable, 5 of 20 patients (25%) having definitive reconstruction at over 12 months developed recurrent hernia and/or required adjunctive mesh compared with 4 of 53 patients (7.6%) having definitive reconstruction at less than 12 months. While those differences in reconstruction delay were not statistically significant ($P = 0.10$), we believe they are clinically relevant. The average length of initial hospitalization for those 9 developing complications (adjunctive mesh and/or hernia) was 48 days compared with 47.6 days for the 64 reconstructed patients without complications. Therefore, reconstruction complications do not appear to be accounted for by a more severe initial insult. Definitive reconstruction delayed beyond a year likely leads to increased loss of domain making tension-free repair more difficult.

DISCUSSION

Over the past 20 years, there has been a significant evolution of wound management in patients requiring massive fluid resuscitation for treatment of hemorrhagic or septic shock. In 1983, Stone et al reported an important early experience of a novel approach for management of trauma patients who sustained massive intra-abdominal injuries.[11] They noted that these patients frequently died in the perioperative period from complications of hypothermia, coagulopathy, and acidosis resulting from prolonged shock and lengthy surgery. In that report, he noted a substantial reduction in mortality in a group of 17 patients who were treated by vascular repair, ligation of the ends of divided injured bowel, purse string suture of holes in hollow viscera, along with abdominal gauze packing to obtain tamponade. This was followed by rapid closure of the abdomen, thereby reducing hypothermia associated with an open peritoneal cavity and the resultant cycle of coagulopathy, bleeding, and further hypothermia—all resulting in the nearly uniform outcome of early death. That approach gradually took hold and a decade later was dubbed "damage control."

A few years after those observations, there arose an increased awareness of patients suffering intra-abdominal hypertension resulting in decreased cardiac output associated with compromised venous return, oliguria, and compromised pulmonary function caused by decreases in diaphragmatic excursion and inadequate gas exchange. Although intra-abdominal hypertension was noted to cause physiologic perturbation as early as the 19th century,[12] its impact clinically has been recognized only in recent years in patients sustaining intra-abdominal catastrophes. The constellation of increased pulmonary pressures, reduced cardiac output, splanchnic hypoperfusion, and oliguria has become known over the last decade as the abdominal compartment syndrome. It was initially recognized in patients with ruptured abdominal aortic aneurysms,[13] and has subsequently been reported in patients with abdominal injury requiring massive fluid resuscitation, as observed in the patients in this report. In addition, it has also been recently reported that secondary abdominal compartment syndrome can result from massive fluid resuscitation for multiple injuries requiring fluid resuscitation for shock in the absence of abdominal injury.[14] The abdominal compartment syndrome results from shock and resuscitation yielding an ischemia reperfusion injury. This ischemia reperfusion injury is similar to that occurring in the lower extremity compartment syndrome. Cellular damage occurs because of ischemia with subsequent cellular membrane dysfunction and intracellular and extracellular edema formation. This capillary leak results in massive edema of the tissues, and notably, the intestines. It is likely that many patients have died in the past with multiple organ failure which was largely initiated from abdominal compartment syndrome and intestinal ischemia contributing to multiple organ failure. As recognition of the abdominal compartment syndrome became widespread, many institutions managing a large trauma volume began a policy of early recognition and prophylaxis. Prophylaxis consists of the avoidance of abdominal compartment syndrome by refraining from abdominal closure when it becomes clear that fascial approximation would be injudicious due to excessive tension.[15,16] This has led to the widespread use of the open abdomen technique as used and reported in this study.

A method of acute wound coverage that has gained increasing support is the vacuum pack approach.[7] Purported advantages include decreased fluid and protein losses. It has also been suggested that this approach will ameliorate loss of abdominal domain during the acute phase, allowing for a higher percentage of secondary fascial closure, thus eliminating the need for the planned ventral hernia. Using the staged

technique, we found 22% were able to have secondary fascial closure after mesh pleating. In contrast, Miller et al reported 70% of their open-abdomen patients were able to have fascial closure with a vacuum-assisted fascial closure technique.[17] We believe that the majority of patients who cannot be treated with secondary fascial closure, with our staged approach, are those who go on to develop multiple organ dysfunction syndrome and/or sepsis and whose edema does not resolve sufficiently to allow fascial closure. In comparisons among institutions, it is not always clear whether similar populations are being compared. We have recently instituted a randomized trial of the vacuum technique versus the absorbable mesh technique reported in this article to find if there are advantages or disadvantages associated with either approach.

A wide variety of techniques have been used in the acute phases of management, and we have used most of them.[1] Until a decade ago, polypropylene mesh was the most commonly used method of maintenance of abdominal integrity with the open abdomen technique. The mesh was sewn to the fascial edges and that approach was successful in maintaining the visceral contents in the peritoneal cavity. However, we and others noted a substantial fistula rate with the use of polypropylene mesh. This mesh is fairly nonpliable and erosion into the bowel commonly occurs. The use of plastic materials (IV, cystoscopy fluid bags) for closure has been reported by many institutions.[4] The appeal of that material is that it is cheap and rapidly available in emergent circumstances. We have used those materials with fairly good success but note that they tend to tear with repeat exploration which is required in many patients, certainly those with abdominal packs. Based on a report reported by Greene et al[18] we began using absorbable mesh for temporary acute closure and believe that material has worked out well. It is relatively inexpensive and we have found that it can be reopened 3 or 4 times without requiring replacement. Over the course of 2 to 3 weeks, granulation develops on the abdominal viscera. During this phase a suppurative interface develops between the granulation tissue and the mesh. At that time, the woven polyglactin 910 mesh is easily removed from the granulation tissue. It has been questioned why absorbable mesh needs to be removed at all. Absorbable mesh comes in 2 varieties, woven and knitted. The woven variety has very tight interstices and is the material we have used because it provides good tensile strength and allows multiple re-explorations. The knitted variety has much larger interstices, and likely becomes more rapidly absorbed, but it has the disadvantage compared with the woven of having less tensile strength. For the woven mesh to become completely absorbed would usually take several more weeks, which leaves a large open wound with the accompanying nutritional and metabolic consequences. We also believe from the current analysis that prolonged granulation of these wounds contributes to intestinal wall breakdown.

Intestinal fistula formation can indeed be a very serious complication of the open abdominal technique. Absorbable mesh seems to minimize but certainly will not eliminate this problem. Over the course of the past decade, we believe we have learned a couple of lessons which should further minimize fistula development. In our early experience, after mesh removal, we performed dressing changes for a couple of days after removal to diminish nosocomial bacterial colonization of the granulated wound in the thought that better skin graft take would occur.[1] We had a few patients during that time who coughed or had bucking of the ventilator in the intensive care unit, resulting in long tears of 1 or more loops of bowel, which were generally very difficult fistula management problems. Recognizing that problem and being unsure that decreasing colonization was a valid concern, in the current series we began immediate STSG of these wounds at the time of mesh removal. We believe that this change in our staged approach has indeed resulted in a lesser likelihood of fistula recurrence and we have not noted a fistula in recent years due to straining and/or coughing. We believe data analysis from this study also points to a second point which should decrease our fistula rate in the future. Although the staged management protocol called for removal of mesh with granulation coverage at 2 to 3 weeks when the viscera were adherent, we in fact noted that there was a cohort of 71 patients who had mesh retention beyond 3 weeks. Of the 10 patients who developed intestinal fistula after mesh insertion, those patients had their mesh removed at a significantly longer time than the patients who did not develop fistulas ($P < 0.04$). We believe this is not only statistically significant but that it is clinically important.

The components separation technique for abdominal wall reconstruction was described by Ramirez et al.[19] The authors described the performance of large relaxing incisions that consisted of incising the exterior oblique component of the anterior rectus muscles bilaterally, combined with separation of the rectus muscles from their posterior fascia. We found that technique was insufficient for most giant defects encountered with the open abdomen technique. We added a modification that allows for more extensive mobilization and local advancement. The modification involves additional division of the internal oblique component of the anterior rectus fascia down to the arcuate line. That addition essentially doubles the mobilization compared with the original description. We believe the 5% recurrent hernia rate, with a reasonable follow-up interval, provides good results for these major abdominal wall defects.

However, there has been 10% of patients who have required small pieces of prostheses as adjuncts to components separation, generally in the upper abdominal portion of the incision where mobilization is more difficult (the area immediately beneath the xiphoid process). We had speculated based on some tight closures in recent months that prolonging the time from initial hospital discharge to reconstruction may

have contributed to the problem with some of the more difficult tight closures. In fact, data analysis demonstrated that delaying time for reconstruction beyond a year indeed appears to contribute to a higher need for mesh as well as a higher recurrence rate. The most likely explanation is a progressive loss of abdominal domain. The STSG stretches over time, leading to continued enlargement of the ventral hernia. This is combined with decreased fascial compliance due to contraction and consequent retraction of the abdominal wall fascia laterally.

In summary, we believe this staged management approach provides a consistent and effective approach for management of the open abdomen. In the acute stage, absorbable mesh provides satisfactory coverage of the abdominal viscera with a low fistula rate. In those wounds that cannot have the mesh pleated with secondary fascial closure, the data demonstrates that coverage of the granulated wound as soon as the viscera is stuck (usually 14 to 21 days) reduces the fistula rate compared with longer periods of noncoverage of the granulating wound. For definitive reconstruction, the modified components separation is the procedure of choice for repair of giant abdominal wall defects. This approach usually avoids the need for prosthetic material. It is associated with low hernia recurrence rates. The data from this study also suggest that abdominal wall reconstruction should be accomplished within 6 to 12 months from initial hospital discharge which will lead to a lower need for prosthetic patches, as well as a lower recurrence rate because of the allowance for a more tension-free repair compared with waiting beyond a year. Presented at the 123rd Annual Meeting of the American Surgical Association, April 24, 2003, Washington, DC.

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Discussions

DR. MARK A. MALANGONI (Cleveland, Ohio): Dr. Fabian, thank you for a wonderful presentation and a very well-written manuscript, and I trust that the membership will read this when it is published.

This report is a uniform approach to the restoration of abdominal continuity in a large number of patients, most of whom developed this problem after abdominal injury. You were able to close a third of these early by tightening or pleating of the mesh, as you described it, and two-thirds had definitive closure by a modified separation of components technique. The additional modification allows closure of a larger abdominal wall defect than had previously been described using natural tissues.

One thing that was in your manuscript that you didn't describe in your presentation was that 10% of the patients who had closure with the modified separation of components technique had permanent mesh implanted in the upper portion of the defect. This is a very good adjunct when you run into this problem and you just can't get any more stretch out of the natural tissues. I have a few questions for you.

Why not use definitive closure earlier at the time of mesh removal and avoid the need for later operation? Your data clearly emphasize that you may avoid some complications by doing this, and surely some of your patients would have been well enough to qualify.

Eight percent of the patients developed enterocutaneous fistulas. Our experience with both absorbable and permanent mesh has taught us that the principles to avoid these compli-

cations are to interpose omentum or full thickness skin between the intestinal surface and the external environment, to avoid desiccation of intestinal surfaces, and lastly, when possible, to avoid the septic abdomen. Were these principles followed at your institution? Did the fistulas occur in patients in whom these principles were violated or not able to be followed?

Third, have you considered using a vacuum-assisted closure device to reduce the size of the defect and facilitate earlier closure? Experience has suggested that about 50 to 80% of these defects can be diminished in size in a relatively short period of time. Please comment.

My last question is, certainly you must have had some unplanned reoperations during the first 2 stages. Please share the techniques that you used in these circumstances to minimize blood loss during dissection and to avoid unintentional enterostomy which will lead to entercutaneous fistulas.

This is another very important contribution of the Memphis Group to the improvement of care of in the critically injured patient and I thank you very much for the privilege of discussing it.

Dr. Timothy C. Fabian (Memphis, Tennessee): Thanks, Dr. Malangoni. Relative to your earlier definitive closure, I think that is a very important issue, only about 1 in 4 of ours, in fact, could be pleated and closed. There is some suggestion that the vacuum-packed type of approach may increase it to 40 to 50%.

However, I think it is important to look at the patient population you are managing. Ten percent of our patients with laparotomy over the study time period had open abdomen management. I wonder what percentage those represent in other series. In other words, are they less seriously injured patients, allowing for more rapid pleating and closure because of the fact that they have less shock? I don't know that. I believe it is important in these retrospective studies to at least mention the denominator, which may provide some gross comparison between studies. But we have just recently begun a prospective randomized study of the vacuum-packed approach that you have alluded to compared with absorbable mesh and hopefully within a couple of years we will have some data to address this subject more appropriately.

As far as the techniques to avoid fistula using omentum and the like, we do that as often as we can. As you know, many of these patients will not have adequate omentum or have omentum which has been already involved in the inflammatory process rendering it not always adequate. But yes, we make an attempt.

As far as intra-abdominal sepsis is concerned, about 25% of these patients will ultimately develop intra-abdominal abscesses. We either percutaneously drain - with interventional radiology. Or if it is early enough, we will go back in and re-explore them through their mesh. Re-exploration through the mesh is very common in our experience. We do it two, three, 4 times on some of the patients.

Dr. Charles E. Lucas (Detroit, Michigan): Based on a 30-year personal experience of over 100 patients undergoing what I call bilateral external oblique advancement flap as the definitive technique for closure in your so-called stage III patients with these giant defects, I concur with what Dr. Fabian has told us today, namely, you can almost always get a primary closure without foreign body and you have a remarkably, remarkably low incidence of long-term herniation in patients who have a functional abdominal wall.

For those interested in taking on these challenges, I would recommend a modification in technique, namely, dividing the external oblique at the midaxillary line, extending the division superiorly up to involve all of the short ribs, going to within 3 cm of the lateral border of the sternum, extending inferiorly to go within 1 cm of the anterior superior spine and the inguinal ligament down to within 4 cm of the midline, thus dividing all of the laterally based blood supply so that you are relying totally on your transabdominal collateral coming through the branches of the superior and inferior epigastric vessels. One can easily get 12 cm bilaterally and close defects of 25 cm in width using this technique.

Although I have had no deaths, I have had 3 complications related to subcutaneous fat necrosis, probably because I dissected too much fat off of the fascia and didn't keep it with the skin side of the dissection. Dr. Fabian, have you had that complication? And if you haven't, in patients with previous transverse incisions how do you avoid it?

Another problem I have had was referred to by Dr. Fabian, and that is getting a tension-free closure in the area over the xiphoid and immediately inferior to the xiphoid, thus necessitating xiphoidectomy and creation of flaps of the anterior rectus sheath which are imbricated upon each other to get primary closure. Dr. Fabian, do you have any special techniques for getting that last little bit of closure over the xiphoid and immediately inferior to the xiphoid?

I hope the membership study this paper very closely so that it can be 1 of the papers which leads us away from putting in mesh, which causes all sorts of problems in these patients. Nice paper, Dr. Fabian.

Dr. Timothy C. Fabian (Memphis, Tennessee): Thanks, Dr. Lucas. Relative to skin breakdown and fat necrosis, we haven't had much trouble with fat necrosis. We have lost some skin edges. This most commonly happens in the thinner, healthier patients. Heavier folks tend not to have the problem as much. I see you have done a lot of these, because the same problem that you have trouble with, we do, which is in the subxiphoid region. It is most difficult to mobilize fascia and get it together there. What we do is take the external oblique fascia up on the costal margin a good 6 to 8 cm. That

helps. We almost routinely take out the xiphoid process unless it happens to come together easily. Another thing that is important biologically in these patients who have gone on for a year or more is they develop neo-ossifications frequently in the upper wound. And it is important to excise that material because it gets in the way of reconstructing and mobilizing the myofascial flaps.

Dr. L. D. Britt (Norfolk, Virginia): Dr. Fabian, I too want to commend you and your colleagues for excellent work. Just a quick technical point. It has often been said that you should preserve the fascia until you have the - of closure. I think you highlighted putting a prosthetic mesh to the fascia and that beefs up the fascia a little bit. I have a tendency not to touch the fascia until I have definitively closed. Your comments on that?

Dr. Timothy C. Fabian (Memphis, Tennessee): Dr. Britt, I appreciate that. It is a double-edged sword. If you sew to the fascia, you would probably lose a little bit more fascia. If you sew to the skin, you lose more domain of the abdominal cavity. So we have gone with the former. I am not sure that there is the right answer, but that is the rationale why we have sewn to the fascia.

The authors would like to thank the Association for the privilege of presenting this paper.